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The market potential for plug-in hybrid and battery electric vehicles in Flanders: A choice-based conjoint analysis

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ABSTRACT

This paper considers the market potential for battery electric and plug-in hybrid electric vehicles in Flanders, Belgium. Making use of a large-scale survey conducted in 2011 and applying a choice-based conjoint experiment, it is predicted that by 2020, battery electric vehicles could have a market share of about 5% of new vehicles, and plug-in hybrid electric vehicles could have a share of around 7%. By 2030, these figures could increase to 15% and 29%. The speed of up-take of electric vehicles, however, is sensitive to purchase costs.

1. Introduction

The interest in electric vehicles (EVs) has waxed and waned over recent decades. In the mid-1960s, with concern over air quality, between 1974 and 1981 with concerns about imported petroleum security, and from 1985 with a renewed interest in reducing petroleum import and abatement of pollutants from automobiles.

The interests in modern EVs have arisen largely because of characteristics that differ from conventional petrol or diesel vehicles. Their ecological impact can be less when renewable energy such as wind or solar energy is used, the battery can be charged at home, the running costs are low and their acceleration, up to 50 km/h, is relatively very swift. Nevertheless, EVs still have some disadvantages: the purchase price is on average €10,000–€15,000 higher than conventionally fuelled vehicles, charging a fully drained battery can take up to 8 h, there is a lack of public charging infrastructure, and the driving range is limited to 100–200 km.

2. Methodology

2.1. Choice-based conjoint theory

There are numerous methodologies within the stated preference approach. Conjoint analysis is a multivariate technique that evaluates respondent trade-offs among multi-attribute alternatives to estimate consumers' utility functions (Green et al., 2001). Assuming that consumers choose the alternative that maximizes their utility, the conjoint methods map the preference structure of consumers based on their evaluation of the product's attributes (Lancaster, 1966). From the pool of conjoint techniques, the choice-based conjoint (CBC) methodology uses discrete choice models to collect consumer preferences. The respondents must select the product that fits them best among competing alternatives. This makes the choice experiment more realistic and it gives a better predicted accuracy, especially in market simulations (Chakraborty et al., 2002).

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In the CBC experiment, the respondent is confronted with a choice of alternatives. Each alternative is called a profile and their combination into a competing environment is called a choice-set. Table 1 illustrates a simple choice-set.

First, the respondent has to investigate the vehicle attributes – price, maximum speed and driving range – before evaluating which of the attributes is the most important. The respondent then looks at the attributes and their values. Finally, he/she must choose the vehicle for which the combination of attributes gives the highest utility. This process is called a task. Finally, a non-option is added to the task. This way, the respondent chooses the vehicle that gives him the highest utility, and subsequently indicates whether to purchase the vehicle.

2.2. CBC design

In a CBC experiment, the respondent evaluates the profiles based on the considered attributes and chooses the option that gives them the highest utility. It is assumed that the respondent processes its utility by summing up the utility brought by each attribute. As a result, our experiment needs to include every attribute that can influence the utility of the respondent to simulate as close as possible the real decision making process. The survey, however, needs to limit the number of attributes if the choice task is to be processed effectively by the respondent (Hair et al., 2010). Based on a selection of similar studies, eight vehicle attributes were identified as seen in Table 2.

A test survey was conducted at the yearly Brussels Motorshow (January 2011) to help select attributes using face-to-face interviews. The main outcome was that a factor reflecting the prestige and quality of the car was missing in the model the car purchase model and thus "brand-image-design-quality" was added. Further, to ensure respondents interpret vehicle attributes the same way, in the final survey, before starting the CBC experiment, they received an overview of all vehicle attributes setting out their measurement and definition (Table 3).

The attribute levels have to be communicable (Hair et al., 2010). The selected levels, as illustrated in Table 4, were therefore indicated by quantitative measures that can easily be understood by respondents.

Within refuel or charging time, the first level refers to inductive charging systems, where the battery of the electric vehicle is charged when driving or standing still on an installed coil, in which a magnetic field is created. Also, the vehicle attribute "brand/image/design/quality" is expressed on a one to five star scale to make the vehicle attribute actionable. The respondent has to make a trade-off between levels and thus has to be able to compare attribute levels.

After identifying the attribute levels, prohibited pairs are eliminated. This approach involves the elimination of any unbelievable profiles resulting from inter-attribute correlation. For example: when the randomized CBC design chooses the "never" level from the refuel or charging time vehicle attribute, two other attributes become obsolete: driving range and refuel or charging infrastructure alongside the road. At that moment, both attributes are set to "not applicable".

The respondents do not rate the alternatives; they choose the best option. Adding many profiles in the choice-set does not entail a rich added statistical value. However, studies have shown that respondents are efficient with processing choice-sets with up to four profiles (Orme, 2009). In this experiment, three profiles were given in each choice-set. Johnson and Orme (2002) suggest this is a good number of profiles, whilst not burdening the respondents.

To generate partial fractional designs, we used the shortcut method (Johnson, 1994) because it satisfies the most the additive rule assumption. This ensures that only main effects are considered in the model. Three hundred questionnaires were generated, each with ten choice tasks. In practice, one questionnaire version is sufficient to design. Multiple versions provide the shortcut method with more flexibility in respecting the orthogonality of the questionnaires as it can produce a wider range of unique choice tasks. The respondents thus answer a larger set of trade-offs, reducing potential biases of a unique questionnaire.

After the results of the conjoint analysis have been gathered, the information has to be processed using a utility estimation method. Multiple regression and multinomial logit models have been a standard during many years for estimating the conjoint model. However, the development of the Bayesian estimation method (Hierarchical Bayes, HB) has recently changed the landscape (Hair et al., 2010). It provides an accurate method to estimate individual level utilities, keeping the heterogeneity of the population intact (Gelman et al., 2009). In particular, HB has proved to be efficient and accurate with CBC experiments (Wellman and Vidican, 2008). It is therefore the selected method to estimate the utilities for this experiment.

3. Results

The target group for this survey was citizens of Flanders, older than 18 years. The data collection in May 2011 was in collaboration with a recognized market research company (iVOX) and involved 2037 people of which 1197 fully responded. The

Table 1
Choice-set.

	Vehicle A	Vehicle B	Vehicle C
Price	€12,500	€17,500	€15,000
Maximum speed	160 km/h	180 km/h	150 km/h
Driving range	400 km	600 km	500 km

Table 2
Choice of vehicle attributes based on similar CBC studies.

Similar studies	Attributes							
	Travel cost per 100 km	Purchase costs	Environmental performance	Refuel or charging infrastructure	Driving range	Refuel or charging time	Annual costs	Maximum speed
Hidrue et al. (2011)	✓	✓	✓		✓	✓		
Achtnicht et al. (2008)	✓	✓	✓	✓				
Potoglou and Kanaroglou (2007)	✓	✓	✓	✓			✓	
Horne et al. (2005)	✓	✓	✓	✓				
Brownstone et al. (2000)	✓	✓	✓	✓	✓	✓		✓
Ewing and Sarigöllü (1998)	✓	✓	✓		✓	✓	✓	
Bunch et al. (1993)	✓	✓	✓	✓	✓			
This study	✓	✓	✓	✓	✓	✓	✓	✓

Table 3
Definition of vehicle attributes.

Vehicle attribute	Definition
Purchase costs	Purchase price, VAT, registration tax and possible governmental fiscal incentives
Annual costs	Insurance, maintenance and yearly driving tax
Travel cost for 100 km	Fuel or electricity cost for 100 km
Environmental performance	Based on Ecoscore (the higher the Ecoscore, the better the environmental performance of the vehicle)
Refuel or charging infrastructure alongside the road	Expressed in percentage of current fuel station coverage
Driving range	Number of kilometers that can be driven without refueling or recharging the battery
Refuel or charging time	Time to refuel or charge the battery
Maximum speed	Maximum speed of the vehicle
Brand/image/design/quality	How does the vehicle fulfill the consumers' demand on brand, image, design and quality?

composition of the sample was representative for the Flemish population according to age, sex, education level and region. The entire survey was conducted on a user friendly internet based system to minimize the respondents' effort.

The resulting individual utilities of all vehicle attribute levels are called part-worth utilities. The raw part-worth utilities are rescaled according to the zero-centered diffs method so that their sum within an attribute equals to zero. Next, the adjusted part-worths are again rescaled so that the sum of the differences between the maximum and the minimum levels across all attributes for each respondent equals the number of attributes times a hundred. This way, the part-worths use a common interval scale across the attributes. Hence, they must be interpreted in a relative way and their magnitude is meaningful. Moreover, every level can be compared with one another.

Since the analysis uses the additive rule, the utility of a car is calculated by summing up the part-worths associated to the attributes' value. The vehicle that will be preferred and hence chosen is the one with the highest utility.

The individual part-worth utilities capture the preference structure of the population. By using a choice simulator, the reaction of the demand can be estimated for a market scenario in which vehicles are identified. These vehicles are simulated through a combination of attribute levels. The simulator uses the associated part-worths to calculate the preferred vehicle for each individual. The market shares are deduced from the simulated individual choices. Here, market scenarios are built for 2012, 2020 and 2030 for the Flanders market. In all scenarios, eight types of vehicles are identified; city petroleum car (City P), medium class petroleum car (Medium P), premium class petroleum car (Premium P), city diesel car (City D), medium class diesel car (Medium D), premium class diesel car (Premium D), battery electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV). We included three sub-types of petroleum and diesel vehicles as their market supply is more diversified. The levels for each vehicle type taken into account the expected technological evolution as well as the expected evolution of the energy prices. Also, no level identified as a reversal was used in the scenario simulation. Table 5 illustrates the selected levels for each scenario and portraits the market shares derived from the CBC experiment. These shares are the proportions of newly sold vehicles in Flanders, not of the entire Flemish car fleet.

Conjoint simulation is based on the assumption that consumers choose their new car based on its attributes. It does not take into account other sales factors, such as advertising and promotion that also influence the effective market share. Therefore, the market shares depicted below illustrate the potential market shares. New technologies generally diffuse slowly and need time to significantly affect their potential market share.

The results for the scenario for 2012 are regarded as a validation for our model. We compare the results with the 2010 Belgian market for newly sold vehicles. In 2010, diesel vehicles had a 76% market share, followed by petroleum cars with 23.3% and BEVs with 0.01% (FEBIAC, 2011). No PHEVs were available on the Belgian market in 2010. These data can be compared to that for the 2012 scenario seen in the table.

Table 4
Measurement, number and magnitudes of attribute levels (Based on Horne et al., 2005).

Purchase costs	Annual costs per year	Travel costs per 100 km	Environmental performance (Ecoscore)	Refuel or charging infrastructure (%)	Driving range (km)	Refuel or charging time	Maximum speed (km/h)	Brand/image/ design/quality
€10,000	€500	€0	60	5	100	Never	80	1 Star
€12,500	€1000	€2	65	10	150	5 min (station)	100	2 Stars
€15,000	€1500	€4	70	20	200	10 min (station)	120	3 Stars
€17,500	€2000	€6	75	40	300	2 h (home) and 10 min (station)	140	4 Stars
€20,000	€2500	€8	80	60	500	8 h (home) and 5 min (station)	160	5 Stars
€22,500	€3000	€10	85	80	750	8 h (home) and 30 min (station)	180	
€25,000	€3500	€12	90	100	1000	8 h (home)	200	
€30,000	€4000	€15	95	120	1250			
€35,000	€4500			150				
>€35,000	>€4500							

Table 5
Scenario setup and results.

	Purchase costs	Annual costs per year	Travel costs per 100 km	Environmental performance	Refuel or charging infrastructure (%)	Driving range (km)	Refuel or charging time	Maximum speed (km/h)	Quality/ design/ brand/ image	Market shares (%)
Scenario 2012										
City P	€12,500	€2000	€6	65	100	500	5 min (station)	140	2 Stars	
Medium P	€17,500	€2500	€8	65	100	500	5 min (station)	160	3 Stars	18
Premium P	€25,000	€2500	€10	60	100	750	5 min (station)	160	3 Stars	
City D	€12,500	€2000	€4	65	100	750	5 min (station)	140	3 Stars	
Medium D	€17,500	€2000	€4	60	100	750	5 min (station)	160	4 Stars	77
Premium D	€25,000	€2500	€8	60	100	1000	5 min (station)	160	4 Stars	
BEV	€30,000	€1500	€2	90	5	100	8 h (home)	120	1 Star	1
PHEV	€35,000	€2000	€4	80	100	750	5 min (station)	160	2 Stars	4
Scenario 2020										
City P	€12,500	€2000	€6	70	100	500	5 min (station)	140	2 Stars	
Medium P	€17,500	€2500	€8	70	100	500	5 min (station)	160	3 Stars	18
Premium P	€25,000	€2500	€10	65	100	750	5 min (station)	160	3 Stars	
City D	€12,500	€2000	€4	70	100	750	5 min (station)	140	3 Stars	
Medium D	€17,500	€2000	€6	65	100	750	5 min (station)	160	4 Stars	70
Premium D	€25,000	€2500	€8	65	100	1000	5 min (station)	160	4 Stars	
BEV	€25,000	€1500	€2	90	20	150	8 h (home)/30 m (station)	140	2 Stars	5
PHEV	€25,000	€2000	€4	80	100	750	5 min (station)	160	2 Stars	7
Scenario 2030										
City P	€15,000	€1500	€8	80	100	750	5 min (station)	140	3 Stars	
Medium P	€20,000	€1500	€10	80	100	750	5 min (station)	160	4 Stars	28
Premium P	€25,000	€1500	€12	80	100	1000	5 min (station)	160	4 Stars	
City D	€15,000	€1500	€8	80	100	750	5 min (station)	140	3 Stars	
Medium D	€20,000	€1500	€10	80	100	750	5 min (station)	160	4 Stars	28
Premium D	€25,000	€1500	€12	80	100	1000	5 min (station)	160	4 Stars	
BEV	€25,000	€1500	€4	95	60	200	8 h (home)/5 m (station)	140	3 Stars	15
PHEV	€25,000	€1500	€6	90	100	1000	5 min (station)	160	3 Stars	29

The model is able to explain the underlying reasons of the market shares based on the influences of the part-worths. Plug-in hybrid electric vehicles cost around €5000–€10,000 more than that of a conventional cars but offer benefits of a higher environmental scores and cheaper driving costs[1] when running on ecological produced electricity. However, even though PHEVs are more expensive than BEVs, its market share is higher. This is due to the flexibility the PHEVs can deliver: they have a similar range to conventional cars, they can use the existing fueling infrastructure and they can refuel in five minutes. Still, the market shares of PHEVs and EVs remain marginal compared to conventional petrol and diesel vehicles.

[1] Gasoline excise tax in Belgium is the rate of €637.67 per 1000 l in 2012. There is no excise tax on electricity.

Table 6
Sensitivity analyses: the effect on the market shares.

Action	Effect on attribute levels	Market share BEVs (%)	Market share PHEVs (%)	Total EV market share (%)
Base scenario 2012		1.23	3.61	4.84
Higher reduction in purchasing costs	Purchase price of BEVs and PHEVs decrease with €5000	2.74	6.57	9.31
More charging infrastructure	Infrastructure coverage develops from 5to 10%	1.99	3.52	5.51
Rise of fuel prices	Travel costs for diesel and petroleum cars rise with €2 per 100 km	1.68	6.08	7.76
Battery leasing	Purchase price of BEVs decrease with €10,000 and annual costs increase with €1000	1.64	3.73	5.37
More battery capacity	Driving range for BEVs increases from 100 km to 200 km	1.63	3.51	5.14
More battery capacity	Driving range for BEVs increases from 100 km to 300 km	2.82	3.33	6.15
Faster charging time	Fast chargers are available in public areas and take 30 min to recharge the battery	1.36	3.73	5.09

In 2020, the BEV and PHEV markets will increase. Still, the market share of PHEVs will be higher than that of BEVs (7% versus 5%). Both electric vehicle technologies will have an increased market potential because of technical and economic enhancements: battery costs will drop, BEV range will improve and charging times will be shorter. Moreover, the charging infrastructure will be more developed and the maximum speed of BEVs will increase.

But it is in 2030 that our analysis suggests BEVs and PHEVs will become a real potential alternative for conventional cars. Our simulations show that demand will create a potential market share of 15% for BEVs and 29% for PHEVs. Next to improvements in driving range, charging infrastructure, shorter charging times, and more competition between the EV producers, the main driver is the rising energy price. Even when taking into account increased electricity prices, the market potential for conventional cars still decreases.

To better understand consumer acceptance for BEVs and PHEVs, we investigate the influence on the market share for actions, both from a policy and manufacturer's point of view. Our base scenario is 2012. This sensitivity analysis enables to indicate interesting recommendations to stimulate the introduction of electric vehicles in Flanders. Table 6 illustrates the results for the sensitivity analyses.

The adoption of BEVs and PHEVs is partly driven by the market price of conventional fuels. Even though governments have little direct influence on the energy market, they can still impact the final consumption price through taxation. By more completely internalizing the full costs of conventional vehicles using diesel and petroleum fuels, this could encourage consumers to switch to electrified models. Here, a €2 increase for petrol and diesel prices increases the market potential for BEVs, by 1.23–1.68%, and PHEVs by 3.61–6.08%.

Increasing the driving range for BEVs from 100 km to 200 km and improving the charging time to 30 min in the street have a similar effect on BEV and PHEV market potential. The market share for electric vehicles rises to respectively 5.14% and 5.09%. However, given the findings of the consumer sensitivity for purchase costs, we can conclude that research should be rather oriented on decreasing the costs of the battery rather than increasing the driving range or lowering charging time. The development of the charging infrastructure, coverage of 10% of filling stations, increases only the market potential for BEVs by 1.23–1.99%. The PHEV market potential is little affected because these vehicles are meant to be charged at home.

4. Conclusion

Looking at scenarios for 2012, 2020 and 2030 for the potential up-take of battery electric and plug-in hybrid electric vehicles in Flanders, we found that while sales figures in 2012 will still be low, by 2020, these number of new purchases could rise to 5% for BEVs and 7% for PHEVs because of technological improvements and a decline in purchase costs. In 2030, electrified transport could attain a market share of 15% for BEVs and 29% for PHEVs. In terms of drivers, the up-take of these vehicles is most sensitive to vehicle sales prices, the price of fuel for conventional cars and the pace of technological change; e.g. the market shares for electrified transport would rise from 4.84% to 9.31% with lower purchase costs and to 7.76% with higher conventional fuel prices. Increasing the driving range for BEVs to 300 km would entail an increase to 6.15%.

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